OAK MORTALITY EVALUATION

at

CUYAHOGA VALLEY

NATIONAL PARK

2001

Prepared by:
Rod Whiteman

and

Brad Onken

USDA Forest Service
Northeastern Area
Forest Health Protection
Morgantown, WV 26505

ABSTRACT

In 1999, approximately 4,400 acres of gypsy moth defoliation occurred at the Cuyahoga Valley National Park resulting in significant tree mortality. Surveys conducted in 2000 and 2001 revealed 124 pockets of mortality totaling 1,175 acres. Oak mortality throughout these areas averaged approximately 54 percent. Also, approximately 2 percent of the oaks had a significant amount (21-99%) of branch dieback. While the southeastern and western aspects had the highest number of areas of mortality, heavier concentrations occurred on eastern and northwestern aspects. In general, mortality was heavier on lower slopes and lighter on upper slopes throughout the area. There is very little difference in the mortality rates between oak species and between size classes for individual species of oak. However, white oak mortality accounts for nearly two-thirds of the overall oak mortality at Cuyahoga Valley National Park.

INTRODUCTION

Cuyahoga Valley National Park (CVNP) was created by Congress in 1974 and currently encompasses over 33,000 acres, of which the National Park Service owns approximately 18,000 acres. CVNP is located in northern Ohio, between the cities of Cleveland and Akron (Figure 1). CVNP is bordered to the west by I-77 and to the east by SR 8 and is dissected north and south by both I-80 and I-271. Approximately 19,000 acres of forest land is located within the boundary of CVNP. Other land use practices within the park include abandoned fields, agricultural fields, wetlands and suburban areas.

Oak-hickory is the most prevalent forest cover type and covers approximately 70 percent of the forested areas. Ridge tops, plateaus and the valley floor at CVNP are fairly flat and broad with elevations ranging from 730 to 1,030 feet above sea level. The terrain is generally moderately sloping with a number of steep ravines. The Cuyahoga River flows through the entire length of the Park and is fed by a number of small streams throughout the area.

CVNP is a high use recreational area, with over 3.5 million visitors annually. It contains over 120 miles of trails, several day use areas, two visitor centers and an environmental education center. Thousands of commuters travel through the Park daily.

The USDA Forest Service and the CVNP began monitoring gypsy moth populations in the 1980's using male moth traps, aerial surveys and egg mass surveys. The first egg masses were detected at CVNP in 1994 at which time site-wide populations averaged only seven egg masses per acre. Gypsy moth-caused tree defoliation was first noticed in 1995 on 4 acres and increased over the next three years, reaching 185 acres by 1998. Defoliation peaked in 1999 at approximately 4,400 acres and coupled with a severe summer drought, significant tree mortality was already being detected as early as August of that year.

To prevent defoliation and further tree mortality, a 7,140 acre gypsy moth suppression project was implemented in 2000. Only 16 acres within the treatment areas received any noticeable defoliation. No further defoliation occurred at CVNP in 2001 and gypsy moth populations have generally collapsed throughout this area.

Although most of the forested areas have not been defoliated more than once, mortality is very extensive. The mortality varies from a few widely scattered trees per acre to areas where the majority of the oaks are dead. Scattered tree mortality occurs from one end of CVNP to the other but most of the mortality is concentrated toward the center of the Park.

The purpose of this report is to delineate the mortality areas, quantify the damage by species, size class, slope and aspect and list possible consequences of the mortality.

METHODS

To get an accurate account of the size, shape, location and intensity of the mortality at CVNP, an aerial photo mission was conducted on August 29, 2000. Color infrared 1:8000 scale photographs were taken of the entire site. These aerial photos were then interpreted and the mortality was delineated and mapped onto 1:24,000 scale topographic maps. Due to the size of CVNP and the extent of mortality, areas containing mortality of less than one half of an acre or areas with widely scattered mortality of less than 10 percent were not mapped. Delineated mortality was classified as follows:

Light = 10-25 percent of basal area
Moderate = 26-50 percent of basal area
Heavy = >50 percent of basal area

On July 16-20, 2001, a survey was conducted at CVNP to verify the results of the aerial photo interpretation and to assess the mortality with respect to tree species, size class, slope and aspect. The survey consisted of 10-basal area factor (BAF) prism plots that were systematically distributed throughout each of the delineated areas of tree mortality. The following guide was used to determine the number of sample points.

Size of area	Number of plots
.5 – 1 acre	2
1.1- 5.0 acres	4
5.1 – 10 acres	6
10.1 –15 acres	8
15.1 – 20 acres	10
each additional 5 acres	requires additional 2 plots

Using the guide, 4 plots would be established in an area 3 acres in size while 13 plots would be conducted in an area of 27 acres. At each plot, tree species, diameter breast height (DBH) and crown condition were recorded for all "in" trees. The DBH was recorded to the nearest 2" size class while crown condition was recorded using the following tree health criteria:

Healthy	= less than 5 percent branch dieback
Slight decline	= 5-20 percent branch dieback
Moderate decline	= 21-50 percent branch dieback
Severe decline	= 51-99 percent branch dieback
Dead	= no live foliage

Slope and aspect were recorded at every plot. Slope was classified in four categories (0-2%, 3-10%, 11-25%, and 26% and greater) while aspect was rounded to the nearest 5 degrees. General observations of the type and abundance of regeneration were also recorded at each plot.

RESULTS

A total of 286 plots were conducted in 63 delineated areas. The plots encompassed a total of 2,907 trees and included 27 tree species. Due to time constraints, plots were not conducted in all 124 delineated mortality areas. Tree species are listed below in descending order of abundance and further referenced in Tables 1-9.

Common Name	Scientific name	Acronym
white oak	Quercus alba	WO
northern red oak	Quercus rubra	RO
black oak	Quercus velutina	BO
sugar maple	Acer saccharum	SM
red maple	Acer rubrum	RM
hickory	Carya spp.	H
yellow poplar	Liriodendron tulipifera	YP
American beech	Fagus grandifolia	AB
black cherry	Prunus serotina	BC
white ash	Fraxinus americana	WA
misc sp.*	(no scientific name)	misc sp
scarlet oak	Quercus coccinea	SO
swamp white oak	Quercus bicolor	SWO
shingle oak	Quercus imbricaria	SHO

* = This group is comprised of American basswood, eastern hemlock, elm species, black gum, big tooth aspen, black locust, sassafrass, hop-hornbeam, black walnut, white pine, American hornbeam, cucumber, yellow buckeye and flowering dogwood. None of these species accounted for more then 1 square foot basal area in any mortality classification.

The degree of tree mortality estimated by photo interpretation was accurate approximately 75 percent of the time. Most of the incorrect ratings were near mortality thresholds. For example, an area that had a 27 percent mortality rate was incorrectly classified as light mortality or an area that had 24 percent mortality was incorrectly classified as moderate. Although the photo interpretation provided the best means of delineating the affected areas, the actual intensity of mortality is better evaluated using ground surveys.

At CVNP a total of 32 areas encompassing 246 acres have light mortality, 72 areas encompassing 697 acres have moderate mortality and 20 areas encompassing 232 acres have heavy mortality (Figure 2).

The data for the areas of heavy mortality are summarized and presented in Tables 1-3. Table 1 shows both the basal area per acre and number of trees per acre by species and crown condition. For example, dead white oaks account for a basal area of 41.0 square feet per acre, while 6.9 square feet per acre are healthy and 1.1 square feet per acre are declining. The declining category is comprised of moderate (21-50 percent) and severe (51-99 percent) branch dieback. Table 2 presents the basal area per acre of various tree groups by DBH class and tree condition. From the table, total basal area in the heavy mortality areas average 96.6 square feet per acre, of which 72.2 are oak species. In the 16-18" DBH class, oak species account for 27.3 square feet per acre, of which 4.7 square feet are healthy, 21.9 square feet are dead and 0.7 square feet are declining. Table 3 presents the number of trees per acre by DBH class and tree condition. Tables 4-9 present the data in a similar fashion for the moderate and light mortality areas.

The oak component in each of the three mortality classes is fairly similar. Oak species comprise 75 percent of the basal area in the heavy class, 65 percent in the moderate and 72 percent in the areas with light mortality. Looking at the number of trees per acre, oak species comprise 37 percent in the heavy, 34 percent in the moderate and 42 percent in the light mortality areas. Oaks account for 98 percent of the dead trees in the heavy class, 97 percent in the moderate and 95 percent in the light class. In the 63 areas cruised, oak mortality exceeded the mortality of all other species combined.

Oak mortality rates were summarized by size class for each of the mortality classes and presented in the table below. For a given intensity class, oak mortality rates are fairly similar between size classes. The 2-5" DBH class was not included in the table due to the small number of trees and basal area per acre.

Percent oak mortality by DBH and mortality intensity class.

Mortality Class	DBH Class				Average *
	6-10"	12-14"	16-18"	20" +	
Heavy	87%	82%	80%	70%	80
Moderate	52%	63%	50%	59%	56
Light	43%	26%	30%	26%	31
All classes *	61%	57%	53%	52%	56

* = Values represent the arithmetic mean.

White oak, black oak and red oak account for the vast majority of the oak component at CVNP. Other oak species combined account for less than 5 percent of the overall basal area and number of trees per acre in the mortality areas.

Mortality rates for these three species were used to determine a weighted average by size class as well as the overall mortality within species in the table below. Interestingly there is little difference in the rate of mortality between species and size class.

Percent mortality by size class for individual species of oak.

Species	DBH Class				Weighted Average
	6-10"	12-14"	16-18"	20" +	
WO	54%	55%	54%	60%	55%
BO	50%	52%	56%	53%	54%
RO	59%	50%	57%	51%	53%

Although the mortality rates for the three oak species were fairly similar, white oak accounts for approximately 66 percent of the oak basal area and the number of trees per acre. Thus, white oak mortality accounts for approximately two thirds of all oak mortality and three fifths of all tree mortality at CVNP.

Oak mortality of the three major species can be further examined in each mortality class as shown in the following table. Mortality rates were very similar between black and red oaks in any given mortality class. The white oak mortality however, was much higher than these two species in the heavy and moderate class but much lower in the light class.

Percent mortality by intensity class and individual oak species.

Species	Mortality class		
	Light	Moderate	Heavy
WO	30	60	84
BO	49	48	66
RO	49	48	63

White oak, black oak and red oak all have fairly similar rates of declining trees. Black oak had the highest rate of 2.6 percent, white oak had 2.4 percent while red oak had the lowest rate at 1.5 percent.

The mortality at CVNP was also analyzed to see if it was influenced by slope and aspect. During the cruise, slope was recorded into one of four slope categories for each individual plot. Individual plot data was then summarized for each slope category to calculate oak mortality. The oak mortality rate for the 0-2%, 3-10% and 11-25% slope categories is presented in the following table. The 26 percent and greater category was not presented because it was based on only four plots. Oddly, oak mortality decreased as slope increased.

Oak mortality by slope category

Slope Category		
0-2%	3-10%	11-25%
65.7%	60.2%	52.8%

Aspect was divided in 8 categories, each spanning 45 degrees. The number of acres of mortality was calculated for each aspect category and is presented in the following table. The southwestern and western aspect had the highest number of acres of tree mortality and together account for nearly a third of the total mortality. The southeastern aspect had the smallest number of mortality acres.

Mortality acres by aspect

Aspect	Degrees	Acres of tree mortality
N	337.5° – 22.5°	161
NE	22.5° – 67.5°	128
E	67.5° – 112.5°	118
SE	112.5° – 157.5°	99
S	157.5° – 202.5°	142
SW	202.5° – 247.5°	201
W	247.5° – 298.5°	173
NW	298.5° – 337.5°	153

Slope and aspect were examined together using the categories previously mentioned. Percent oak mortality was calculated for each slope and aspect combination and is presented in Table 10. The highest rate of mortality occurred on southern aspects with a 0-2 percent slope while the lowest rate of mortality was obtained on western aspects with an 11-25 percent slope. The majority of the mortality rates ranged from 40-70 percent. Although the southwestern and western aspects had the highest number of acres of mortality, the eastern and northwestern aspects had the most intense mortality.

From 1998-2000, gypsy moth caused tree defoliation was detected on a total of 4,803 acres at CVNP. Discounting the 127 acres that have been defoliated more than once, 4,614 acres of forest land have been defoliated since 1998. Over this three year period, approximately 99 percent of the defoliation has been heavy. So, for all practical purposes, the defoliation history of the defoliated area can be regarded as one heavy defoliation with 90 percent of it occurring in 1999. Figure 3 presents the defoliation survey results from 1998-2000.

Most, if not all, of the 1,175 acres of mortality can be linked to this gypsy moth defoliation. Oak species are a highly preferred food source of the gypsy moth and oaks account for approximately 97 percent of the mortality in the delineated areas. The mortality rate on oak species in the delineated areas is approximately 54 percent and oaks account for the vast majority of the trees that have moderate (21-50%) and severe (51-99%) branch dieback.

Kevin_Skerl@nps.gov
03/02/2004 05:35 PM

To: rwhiteman@fs.fed.us
cc:
Subject: Oak Mortality GIS data

Rod,

I have been asked for the GIS data for the mortality report, and I see that the one file I have (mort00.shp) is not the data that is represented on the maps in the report - indeed it appears to be an incomplete draft of the data. Is it possible to get the final dataset for the Oak Mortality Evaluation (2001)? Thanks again.

We are doing a Fire Management Plan and this info will be useful for planners.

-Kevin

Kevin L. Skerl, Ecologist
Science and Resource Management Division
Cuyahoga Valley National Park
National Park Service
15610 Vaughn Road
Brecksville, Ohio 44141

Voice: 330-650-5071 ext.4
Fax: 440-546-5943
Email: kevin_skerl@nps.gov
Web: www.nps.gov/cuva

Oak regeneration at most of the plots was scarce to non-existent. Oak regeneration was detected on less than 10 percent of the plots. Regeneration was highest in the heavy mortality class but was generally comprised by herbaceous material, red maple and to a lesser degree, black cherry and sugar maple.

DISCUSSION

Mortality following gypsy moth defoliation has been documented by several sources over a long period of time. Kegg (1971), the Allegheny National Forest (1988), the West Virginia Division of Forestry (1997) and Quimby (1985) all reported significant mortality after gypsy moth defoliation. These case histories report a range of oak mortality from about 15 to 60 percent which is comparable to the level of mortality at CVNP. The high level of mortality at CVNP would have likely been less had the 1999 defoliation event not have coincided with a severe drought event. In an average year at CVNP, precipitation in May and June should be approximately 3.50 and 3.70 inches, respectively. In 1999, May precipitation was only 1.66 inches and June was 2.69 inches. Rainfall totals for these two months combined was approximately 60 percent of the normal amount. This early growing season rainfall deficit created additional stress on the trees.

It was somewhat surprising that the mortality rate was about the same for all sizes of trees. Work by Hicks and Fosbroke (1987) indicated that a disproportionate amount of mortality occurred on large trees. If anything, our results show a slight decrease in mortality rate as the size of the tree increased.

Another interesting aspect was that the mortality rate was fairly similar for white oak (55%), black oak (54%) and red oak (53%). Work by Statler and Serrao (1983) found greater mortality among red oaks while Gansner and Herrick (1982) found greater mortality in the white oak group.

Also surprising are our results when aspect and slope are considered. Although Hicks and Fosbroke (1987) found that higher mortality rates on southern and southwestern aspects and Herrick (1982) found higher mortality rates on southwestern, western and northwestern aspects, our results at CVNP did not indicate such patterns. Although the northwestern aspect had the highest mortality rate, it was only one percent higher than the eastern aspect which had the second highest rate. Also, the northeastern aspect had higher mortality than both the southern and western aspects and was only one percent less than the southwestern aspect. Bess et. al (1947) and Herrick (1982) found that higher mortality were found on poorer growing sites. In most instances, steeper slopes would have less soil moisture and ultimately be poor growing sites. However our results show that as slope increased mortality decreased. This indicates that the mortality was highest on the better growing sites. Hicks and Fosbroke (1987) and Statler and Serrao (1983) also found more mortality on better growing sites.

The high tree mortality rate at CVNP is expected to have several negative impacts. With the loss of mast producing oaks, deer could have a greater impact on the already limited oak re-generation in addition to agricultural crops and ornamentals. There will be both increase in the number of hazard trees and greater fire risk due to an increase in dead and cured fuel. The overstory oak component in these mortality areas will likely be replaced by a less desirable tree

species such as red maple. A temporary increase in water flow, water temperature and a decrease in water quality of several small streams could also occur in some of the more heavily impacted areas.

CONCLUSION

Significant oak mortality on approximately 1,175 acres at CVNP is directly related to gypsy moth defoliation that occurred from 1998 to 2000, especially in 1999 when approximately 4,400 acres were defoliated. This added stress of the 1999 drought greatly enhanced the level of mortality. Future forest management planning should include a contingency for insect and disease monitoring and early intervention should it become necessary.

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Table 1. Basal area and number of trees per acre for individual tree species by tree condition in the heavy mortality areas.

SPECIES	TREE CONDITION	BASAL AREA/ACRE	NUMBER OF TREES/ACRE
BO	Dead	8.3	4.8
WO	Dead	41.0	37.0
RO	Dead	6.4	5.0
SO	Dead	0.6	1.3
non-oaks	Dead	1.1	4.4
BO	Healthy	3.6	1.9
WO	Healthy	6.9	6.1
RO	Healthy	3.1	4.5
SHO	Healthy	0.1	0.1
H	Healthy	2.2	5.3
SM	Healthy	4.9	32.8
RM	Healthy	5.6	14.9
WA	Healthy	0.4	0.3
YP	Healthy	2.9	7.1
BC	Healthy	2.4	16.1
AB	Healthy	1.7	5.5
misc. sp.	Healthy	3.2	21.0
BO	Declining	0.5	0.2
WO	Declining	1.1	0.9
RO	Declining	0.6	0.3
non-oaks	Declining	0.1	0.1

Table 2. Basal area per acre for various tree groups by DBH class in the heavy mortality areas.

Tree Condition	DBH Class					Total
	2-4″	6-10″	12-14″	16-18″	20″	
All Species	3.3	15.2	25.3	30.5	22.3	96.6
Healthy	3.2	10.7	8.1	7.7	7.2	36.9
Dead	0.1	4.5	16.7	22.0	14.1	57.4
Declining	0	0	0.5	0.8	1.0	2.3
Oaks Only	0.1	4.6	20.2	27.3	20.0	72.2
Healthy	0.1	0.6	3.2	4.7	5.1	13.7
Dead	0	4.0	16.5	21.9	13.9	56.3
Declining	0	0	0.5	0.7	1.0	2.2
Non-oak Species	3.2	10.6	5.1	3.2	2.3	24.4
Healthy	3.1	10.1	4.9	3.0	2.1	23.2
Dead	0.1	0.5	0.2	0.1	.2	1.1
Declining	0	0	0	0.1	0	0.1

Table 3. Number of trees per acre for various tree groups by DBH class in the heavy mortality areas.

Tree Condition	DBH Class					Total
	2-4″	6-10″	12-14″	16-18″	20″	
All Species	71.5	43.0	26.9	19.5	8.7	169.6
Healthy	69.0	30.1	8.6	5.0	2.9	115.6
Dead	2.5	12.9	17.8	13.9	5.4	52.5
Declining	0	0	0.5	0.6	0.4	1.5
Oaks Only	2.5	13.2	21.4	17.4	7.6	62.1
Healthy	2.5	1.7	3.4	3.1	1.9	12.6
Dead	0	11.5	17.5	13.8	5.3	48.1
Declining	0	0	0.5	0.5	0.4	1.4
Non-oak Species	69.0	29.8	5.5	2.1	1.1	107.5
Healthy	66.5	28.4	5.2	1.9	1.0	103.0
Dead	2.5	1.4	0.3	0.1	0.1	4.4
Declining	0	0	0	0.1	0	0.1

Table 4. Basal area and number of trees per acre by tree species and tree condition in the moderate mortality areas.

SPECIES	TREE CONDITION	BASAL AREA/ACRE	NUMBER OF TREES/ACRE
BO	Dead	11.4	9.8
WO	Dead	20.3	20.6
RO	Dead	5.0	6.1
SO	Dead	0.6	0.6
non-oaks	Dead	1.3	2.3
BO	Healthy	6.2	5.8
WO	Healthy	12.6	12.0
RO	Healthy	7.2	8.2
SO	Healthy	0.2	0.2
SWO	Healthy	0.2	0.3
H	Healthy	4.7	7.2
SM	Healthy	5.6	28.5
RM	Healthy	8.2	30.5
WA	Healthy	1.1	0.9
YP	Healthy	3.2	5.6
BC	Healthy	2.8	16.3
AB	Healthy	3.2	12.9
misc. sp.	Healthy	4.4	23.5
BO	Declining	0.7	0.6
WO	Declining	1.2	1.1
RO	Declining	0.4	0.2
SO	Declining	0.1	0.1
non-oaks	Declining	0.3	2.1

Table 5. Basal area per acre for various tree groups by DBH class in the moderate mortality areas.

Tree Condition	DBH Class					Total
	2-4"	6-10"	12-14"	16-18"	20"	
All Species	4.3	19.6	23.9	29.6	23.5	100.9
Healthy	3.9	15.2	12.9	17.0	10.6	59.6
Dead	0.3	4.0	10.8	11.5	12.0	38.6
Declining	0.1	0.4	0.2	1.1	0.9	2.7
Oaks Only	0.5	6.5	16.4	22.5	20.2	66.1
Healthy	0.2	2.9	5.8	10.1	7.4	26.4
Dead	0.3	3.4	10.4	11.3	11.9	37.3
Declining	0	0.2	0.2	1.1	0.9	2.4
Non-oak Species	3.8	13.1	7.5	7.1	3.3	34.8
Healthy	3.7	12.3	7.1	6.9	3.2	33.2
Dead	0	0.6	0.4	0.2	0.1	1.3
Declining	0.1	0.2	0	0	0	0.3

Table 6. Number of trees per acre for various tree groups by DBH class in the moderate mortality areas.

Tree Condition	DBH Class					Total
	2-4"	6-10"	12-14"	16-18"	20"	
All Species	84.5	58.2	25.0	18.8	8.9	195.4
Healthy	79.3	44.8	13.1	10.9	3.8	151.9
Dead	3.9	12.0	11.6	7.3	4.6	39.4
Declining	1.3	1.4	0.3	0.6	0.5	4.1
Oaks Only	6.5	19.3	17.8	14.2	7.8	65.6
Healthy	2.6	8.4	6.3	6.4	2.8	26.5
Dead	3.9	10.3	11.2	7.2	4.5	37.1
Declining	0	0.6	0.3	0.6	0.5	2.0
Non-oak Species	78.0	38.9	7.2	4.6	1.1	129.8
Healthy	76.7	36.4	6.8	4.5	1.0	125.4
Dead	0	1.7	0.4	0.1	0.1	2.3
Declining	1.3	0.8	0	0	0	2.1

Table 7. Basal area and number of trees per acre by tree species and tree condition in the light mortality areas.

SPECIES	TREE CONDITION	BASAL AREA/ACRE	NUMBER OF TREES/ACRE
BO	Dead	4.8	5.0
WO	Dead	18.1	22.1
RO	Dead	4.7	3.6
non-oaks	Dead	1.4	10.1
BO	Healthy	9.4	6.4
WO	Healthy	40.6	47.5
RO	Healthy	12.8	9.8
H	Healthy	4.0	6.6
SM	Healthy	14.1	60.1
RM	Healthy	5.0	24.4
WA	Healthy	1.2	1.3
YP	Healthy	2.2	2.0
BC	Healthy	0.8	2.0
AB	Healthy	3.0	8.7
misc. sp.	Healthy	4.8	19.2
BO	Declining	0.2	0.1
WO	Declining	1.4	1.7
RO	Declining	0.2	0.1
non-oaks	Declining	0.2	0.1

Table 8. Basal area per acre for various tree groups by DBH class in the light mortality areas.

Tree Condition	DBH Class					Total
	2-4″	6-10″	12-14″	16-18″	20″	
All Species	4.2	24.1	32.1	49.6	18.9	128.9
Healthy	3.8	18.6	25.2	36.7	13.6	97.9
Dead	0.4	5.3	6.3	12.5	4.5	29.0
Declining	0	0.2	0.6	0.4	0.8	2.0
Oaks Only	0.2	11.5	24.6	39.9	16.3	92.2
Healthy	0.2	6.4	17.4	27.4	11.4	62.8
Dead	0	4.9	6.3	12.1	4.3	27.6
Declining	0	0.2	0.6	0.4	0.6	1.8
Non-oak Species	4.0	12.6	7.8	9.7	2.6	36.7
Healthy	3.6	12.2	7.8	9.3	2.2	35.1
Dead	0.4	0.4	0	0.4	0.2	1.4
Declining	0	0	0	0	0.2	0.2

Table 9. Number of trees per acre for various tree groups by DBH class in the light mortality areas

Tree Condition	DBH Class					Total
	2-4″	6-10″	12-14″	16-18″	20″	
All Species	85.2	71.2	35.1	31.8	7.5	230.8
Healthy	76.7	54.9	27.6	23.5	5.3	188.0
Dead	8.5	15.7	6.8	8.0	1.8	40.8
Declining	0	0.6	0.7	0.3	0.4	2.0
Oaks Only	4.3	33.8	26.4	25.4	6.4	96.3
Healthy	4.3	18.7	18.9	17.4	4.4	63.7
Dead	0	14.5	6.8	7.7	1.7	30.7
Declining	0	0.6	0.7	0.3	0.3	1.9
Non-oak Species	80.9	37.4	8.7	6.4	1.1	134.5
Healthy	72.4	36.2	8.7	6.1	0.9	124.3
Dead	8.5	1.2	0	0.3	0.1	10.1
Declining	0	0	0	0	0.1	0.1

Table 10. Percent oak mortality with respect to slope and aspect.

Aspect	Slope Category	Percent Oak Mortality
N	0-2%	54%
N	3-10%	50%
N	11-25%	51%
N	all	52%
NE	0-2%	70%
NE	3-10%	43%
NE	11-25%	41%
NE	all	59%
E	0-2%	86%
E	3-10%	63%
E	11-25%	55%
E	all	67%
SE	0-2%	52%
SE	3-10%	45%
SE	11-25%	57%
SE	all	47%
S	0-2%	93%
S	3-10%	73%
S	11-25%	46%
S	all	55%
SW	0-2%	58%
SW	3-10%	57%
SW	11-25%	63%
SW	all	60%
W	0-2%	61%
W	3-10%	56%
W	11-25%	35%
W	all	56%
NW	0-2%	63%
NW	3-10%	74%
NW	11-25%	80%
NW	all	68%

Figure 2. -- Tree Mortality at Cuyahoga Valley National Park.

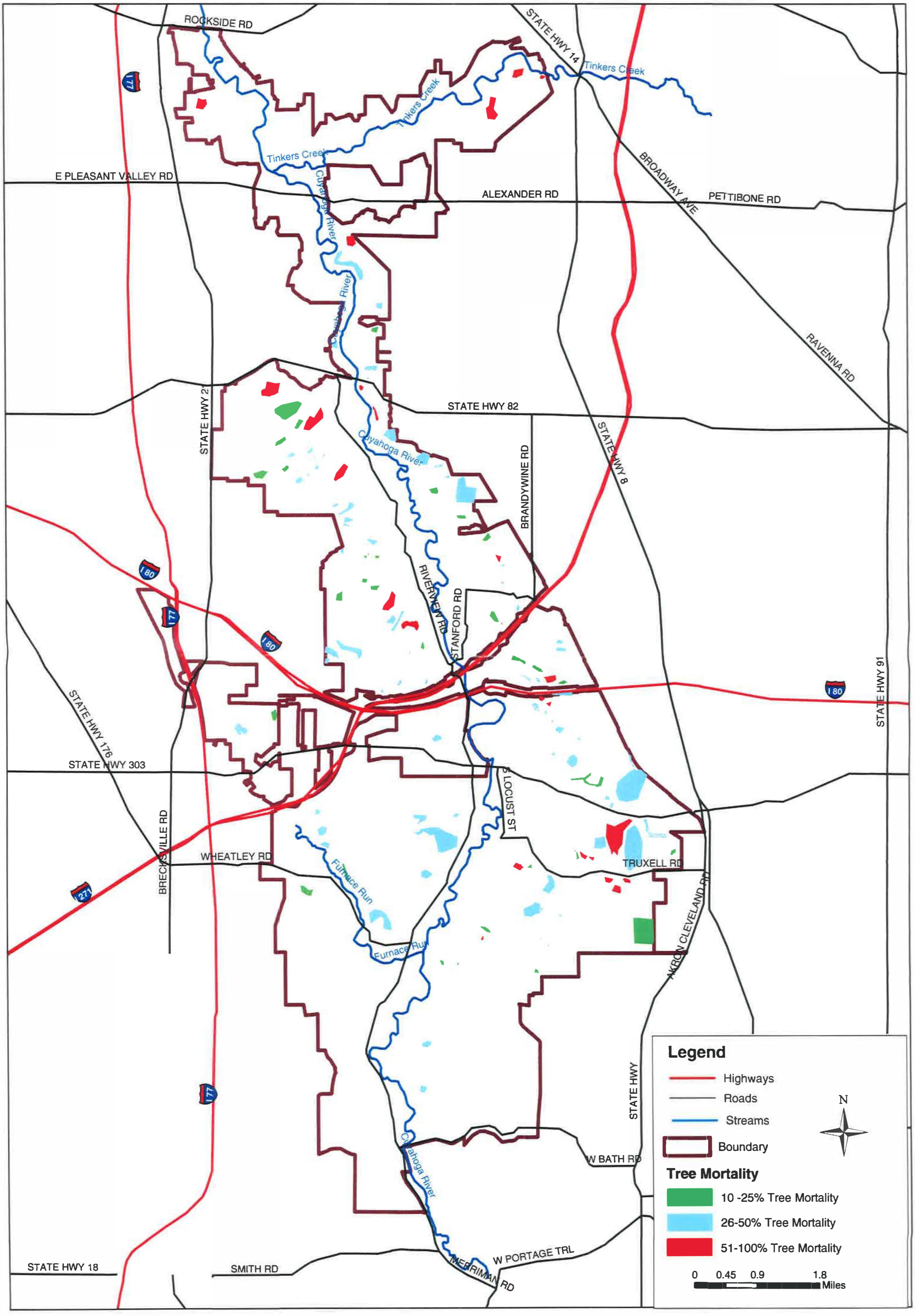

Figure 3. -- Gypsy moth defoliation 1998-2000 at Cuyahoga Valley National Park.